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SUITABILITY OF TEXTURE PARAMETERS FOR CHARACTERIZATION OF HAJDÚ CHEESE RIPENING

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The objectives of this study were to monitor the changes in texture parameters of Hajdú cheese during ripening and shelf-life, and to determine the correlations between the changes in instrumental texture parameters and the age or sensory properties of the product. The mechanical parameters of Hajdú cheese samples made by 5 different manufacturing processes were determined with a QTS 25 Texture Profile Analyser. In addition to mechanical tests, composition analyses and sensory tests were performed. The empirical results of the mechanical tests were evaluated with statistical methods (single-valued and multivariate analysis). The age of the product can be estimated from the texture parameters and processed data as well, despite the sample inhomogeneity, which is due to the manufacturing processes.

Keywords: Hajdú cheese, ripening, instrumental texture parameters, Texture Profile Analyser

Most rennet cheeses are ripened before consumption in order to achieve the desirable sensory qualities. Ripening involves a series of complex biochemical processes, which can be grouped broadly into proteolysis, lipolysis and lactose/lactate metabolism. The extent and type of ripening depend on the duration and temperature of storage, the composition of cheese (especially moisture and salt levels) and the types and activities of enzymes and microorganisms present. The physical and chemical changes that occur during ripening determine the overall sensory qualities of cheese (FARKYE & FOX, 1990).

Hajdú cheese is traditionally made in Hungary from cow milk. It is closely related to Kashkaval cheese, which belongs in the family of Pasta filata (plastic curd) cheeses. Kashkaval cheese, made from sheep milk, has been known since the 11th century. This type of cheese is prevalent in Central and Eastern Europe, primarily in the countries with a Mediterranean climate. Under various names, a number of varieties are produced. These cheeses with a great past have excellent qualities. Their production, however, is limited to a well-defined area. Similarly, types made from cow milk are also well known (KALANTZOPOULOS, 1993). Hajdú cheese is made from raw milk. The curd is produced by the addition of lactic culture and rennet. The technology of manufacture involves a so

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called dipped heat treatment process, during which the curd is kneaded in a specific salt solution. It is a salted and ripened semi-hard cheese with characteristic sensory properties and a relatively high salt content. It is marketed as round blocks weighing 1, 4 or 8 kg, or as half blocks weighing half a kilo, wrapped in airtight plastic foil. Its surface is rindless, smooth, flexible, dry or slightly fatty to the touch and uniformly light-yellow in colour. Its interior is uniformly light-yellow; it has a closed cut surface on which small knobs, chinks and fat inclusions are allowed. It is easy to cut, tender in the mouth and fragile when bent. Its taste and smell are characteristically aromatic, succulent, full and pleasantly salted.

Relatively little data is available in the literature on the structure of Kashkaval cheese and its changes during ripening and shelf-life (MILANOVIC et al., 1998), and even less is known about the imitations made from cow milk. ALY (1994) compared the sensory and proteolytic characteristics and free fatty acid content of a low-fat Kashkaval cheese made from cow milk with a special culture with those of a sample with regular fat content at various stages of ripening. Degree of proteolysis and lipolysis was lower in low fat Kashkaval cheese without addition of special heat- or freeze-shocked cultures than it was in full fat control cheese. Low fat cheese without added cultures did not develop typical Kashkaval flavour and had poor body and texture. Addition of heat- or freeze-shocked cultures increased flavour intensity and cheese body, resulting in low fat cheese with similar flavour and texture to that observed in control cheese at each stage of ripening.

MILANOVIC and co-workers (1998) carried out an electron microscopic study of the microstructure of Kashkaval cheeses made traditionally or from ultra filtered milk with various rennet enzymes. Results showed that milk coagulated using standard chymosin contained smaller casein particles than that coagulated using various rennet enzymes, where fusion of casein micelles into chains and clusters was more advanced. The protein matrices of coagula obtained from UF milk contained a higher proportion of chains than clusters. Casein particle fusion was noticeable in all milk curds, and was most advanced in the curd obtained using standard chymosin.

The rheological properties of a cheese depend upon its structure. The three major constituents of cheese are casein, fat and water. The structural differences between various types of cheese result from the effects of the differences in manufacturing procedures on the structure. During manufacturing, the curd is cut into small pieces so that serum can drain away. The casein matrix thus shrinks on the fat globules, making a more compact structure. The granules formed in this way may then be further distorted, as in the cheddaring process. The final cheese mass is an aggregation of these granules, which forms a secondary structure with its own set of rheological properties. This may still be further modified by subsequent processes, such as milling, which gives rise to a tertiary structure, and by pressing, which distorts the whole cheese. The influence of the salt on the rheological properties of the whole cheese is indirect. A high concentration of salt increases the osmotic pressure, diverting a significant quantity of water from the structural bonds of the casein network (PRENTICE, 1991).

Easily determinable texture parameters which are typical of a given type of cheese can be useful in the testing of the product and in the evaluation of ripening condition. BARA-HERCZEGH and co-workers (2001) made a study of the applicability of mechanical parameters determined with a QTS 25 Texture Profile Analyser to assess the age of Trappist cheese.

The aim of this work was to determine correlations between the texture or mechanical parameters measured and the age of Hajdú cheese in order to be able to estimate the age of the cheese on the basis of such parameters.

1. Materials and methods

1.1. Cheese samples

The Hajdúböszörmény Cheese Plant of Hajdútej Co. provided the raw Hajdú cheese samples wrapped in BK 1L/NE UT Cryovac shrinking-foil, which also served as a ripening cover. The unripe samples weighing 0.5 kg were ripened at 8 °C for 31 days in a climatic chamber at the testing site according to the instructions given by the factory. Samples were taken on days 6, 10, 17, 24 and 31 to monitor the changes. The samples were then stored at 8 °C and tested on days 38, 45, 52, 59 and 66. Altogether, 50 samples were tested from 5 production lots. (The samples were manufactured from October to January.)

1.2. Classification of cheese samples

The main chemical components of the samples, i.e. dry matter content, fat in dry matter and salt content were determined according to the HUNGARIAN STANDARDS (1989 b, c, d), and protein content was determined by the A.O.A.C. (1990) method. The HUNGARIAN STANDARDS (1989 b, c, d) are in accordance with the ISO standards.

Besides determination of the main chemical components of the samples, the quantitative descriptive tests of the Hungarian Standards (an overall maximum score of 20, with weighted factors) were performed during storage (days 38–66) of the cheese (HUNGARIAN STANDARD 1989a, MOLNÁR, 1991). The standard sensory test and its circumstances are found in the previous study of BARA-HERCZEGH and co-workers (2001).

1.3. Determination of texture parameters

In recent years, multifunctional texture test instruments have been developed which are easy to use and suitable for both imitative and empirical tests. Such an equipment is the QTS 25 Texture Profile Analyser (CNS Farnell, England), which evaluates the measured values with the texture profile analysis (TPA) software. The theory of the examination is found in the previous paper (BARA-HERCZEGH et al., 2001).

1.3.1. Testing conditions. A cylinder of 2.5 cm in height with a 90° sector base taken from an inner cheese part of 7.5 cm in diameter was analysed and chewing was modelled with double penetration. The tests were done on two samples using a depth of penetration of 5.00 mm on one sample and a depth of penetration of 10.00 mm on the other one. The test parameters are given in Table 1.

1.3.2. Mechanical parameters investigated. A total of 20 parameters [hardness (1 and 2), cohesiveness, gumminess, chewiness, chewiness index, modulus, adhesive force, adhesiveness, springiness, springiness index area (1 and 2), work done in response to hardness (1 and 2), recoverable deformation (1 and 2), recoverable work done (1 and 2), first peak] were determined by texture analysis with 10 replicate measurements. From the 20 parameters, 17 primary qualities and derived parameters were selected on the basis of importance of the parameter and the reliability of the measurements.

Primary qualities: hardness (1 and 2), cohesiveness, gumminess, chewiness, chewiness index, modulus, springiness, springiness index and area (1 and 2).

Secondary (derived) parameters: work done in response to hardness (2), recoverable deformation (1 and 2); and recoverable work done (1 and 2).

The interpretation of the primary and secondary parameters listed in Table 2 is facilitated by Fig. 1. The figure is from the paper of ARMERO and COLLAR (1997).

1.4. Statistical analysis

Sensory scores were evaluated according to the HUNGARIAN STANDARD (1987). The data from the sensory tests and instrumental TPAs were evaluated statistically (principal component analysis (PCA), principal component regression and regression analysis) by means of the Statgraphics 5.0 software. PCA is a multivariable method for the study and visualisation of the total structure of relationships and for the expression of different characters by a few artificial variables calculated from their correlations (SVÁB, 1979).

Table 1. Parameters of the texture analysis

Test parameters	Value of parameters
Probe:	1.2 cm ∅ plastic cylinder
Type of test:	TPA
Speed of probe:	30 mm min^{-1}
Trigger:	5.0 g
Penetration depth[a]	5.00 mm or 10.00 mm
Number of cycles:	2
Sample temperature:	20–22 °C
Number of analyses:	Each sample was analysed 10 times using different parts of the surface.

[a] The parameter determinations with a penetration depth of 5.00 mm and of 10 mm were termed mode 1 and mode 2 of operation, respectively.

Table 2. Explanation of measured and evaluated texture parameters

Term	Marks[a]	Correlation	Interpretation
Hardness (1 & 2)	*H1, H2*		The force necessary to attain a given deformation. Maximum load during compression cycle 1 or 2
Cohesiveness		*A2/A1*	Total positive work done in cycle 2 divided by total positive work done in cycle 1
Gumminess		*H1×(A2/A1)*	Cohesiveness multiplied by hardness (cycle 1)
Chewiness		*H1×(A2/A1)×L2*	The quantity to simulate the energy required to masticate a solid sample to a steady state of swallowing (gumminess multiplied by springiness)
Chewiness index		*H1×(A2/A1)×(L2/L1)*	Gumminess multiplied by springiness index
Modulus		*tan* α	Fracturability curve of the gradient (when the fracturability is zero, then the gradient of hardness (cycle 1)
Springiness	*L2*		Distance the beam travels to compress the sample in cycle 2
Springiness index		*L2/L1*	Springiness divided by deformation
Deformation	*L1*		Distance travelled by compressing sample in cycle 1 to reach target value
Area (1 & 2)	*A1, A2*		Total positive area in cycle 1 or 2
Work done in response to hardness (1 & 2)	*A4 (in the first cycle)*		Positive area to hardness 1 (or hardness 2)
Recoverable deformation (1 & 2)			Distance travelled by beam whilst sample decompresses from hardness 1 (or 2) to zero in cycle 1 (or 2)
Recoverable work done (1 & 2)	*A5 (in the first cycle)*		Positive area between hardness 1 (or 2) and where load crosses the 0 g point on decompression in cycle 1 (or 2)

[a] The notations are to be found in Fig. 1.

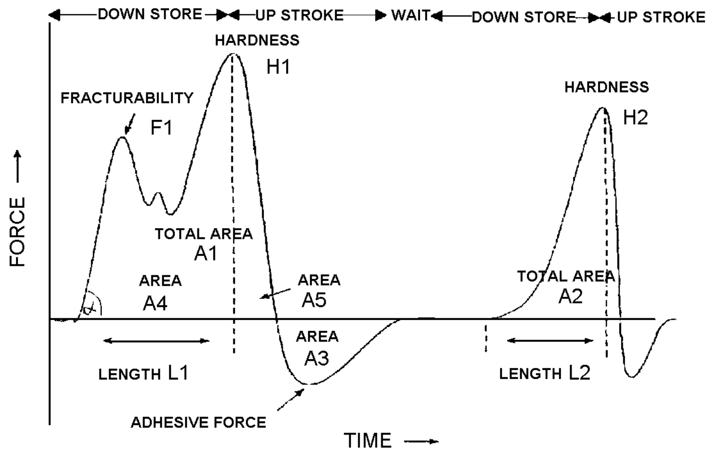

Fig. 1. Interpretation of texture parameters (ARMERO & COLLAR, 1997)

2. Results

2.1. Classification of samples on the basis of chemical composition and sensory tests

Data on the chemical composition of the samples tested are presented in Table 3, and the results of sensory testing during shelf-life in Table 4. These findings reveal that the samples met the standard requirements. After ripening, the products were graded as “excellent” in quality tests, with the mean weighted total score of the sensory tests being 18.44±0.89.

2.2. Selection of texture parameters

Of the 20 texture parameters determined, 17 directly measured values or derived data were selected which could be determined reproducibly (average coefficient of variation <40%) (COCK, 1994). The mean values of the test results on 50 products, with 10 measurements per product, and the mean values of the coefficients of variation of 10 replicate measurements are presented in Table 5.

2.3. Evaluation of texture parameters by PCA

PCA was carried out on 17 variables for all samples. The correlations of the original variables demonstrated that they could be reduced to three principal component variables for the two modes of operation. The eigenvalues of the factors and the cumulative percentages (h^2) are listed in Table 6. The first three principal components cover more than 89% of the variance of the original variables determined with both modes of operation. The importance of the first principal component is expressed by the high eigenvalue (JACKMAN & YADA, 1989).

Table 3. Gross compositional analysis of Hajdú cheese samples

Batch	Chemical composition Dry matter g/100 g	Fat content in dry matter g/100 g	Salt content g/100 g	Protein content g/100 g
I	58.15	47.29	2.98	25.29
II	60.24	45.65	2.11	25.46
III	58.80	45.92	2.58	26.34
IV	58.68	46.86	2.40	27.00
V	56.40	46.10	2.05	26.70
Acceptance range	*57.5±2.5*	*48.0±3.0*	*2.7±0.8*	

Table 4. Results of sensory tests

Batch	Age (days) 38	45	52 Weighted total scores	59	66
I	18.4	19.1	19.2	17.1	14.2
II	18.2	17.2	18.1	17.3	17.3
III	18.1	17.4	15.9	14.0	13.5
IV	18.3	18.7	18.1	17.7	15.3
V	19.2	18.9	16.1	15.5	14.0
Mean	*18.44*	*18.26*	*17.48*	*16.26*	*14.86*

The values of the principal component weights reveal the relative importance of the original variables as compared to each of the respective principal components.

The first principal component is determined by 12 variables to an approximately equal extent in both cases (hardness 1 and 2; gumminess; chewiness; chewiness index; modulus and area 1 and 2; work done in response to hardness 1 and 2; and recoverable work done 1 and 2).

There are two variables in the second principal component with slightly larger weights under both measuring conditions (recoverable deformation 1 and 2). The parameters which determine the third principal component, however, differ under various measuring conditions.

2.4. Estimation of age of product

Texture properties depend on two factors, i.e. the composition of the curd and the degree of ripeness. Since the variations in the characteristics tested during the ripening process differ, all the parameters should be involved in the evaluation of time dependence.

Table 5. Mean values of texture parameters and variation coefficients

Texture parameters (units[a])	Mean	CV[b] (%)	Mean	CV[b] (%)
	Depth of penetration:			
	5 mm		*10 mm*	
Hardness 1 (g)	**10317**	**10**	**13261**	**10**
Hardness 2 (g)	**10569**	**10**	**11655**	**11**
Cohesiveness (none)	**0.971**	**6**	**0.692**	**11**
Gumminess (g)	**9974**	**11**	**9106**	**14**
Chewiness (g mm)	**42120**	**11**	**76168**	**12**
Chewiness index (none)	**8425**	**11**	**9321**	**12**
Modulus (none)	**901**	**9**	**728**	**11**
Adhesive force (g)	184	59	462	48
Adhesiveness (g mm)	432	121	3435	81
Springiness (mm)	**4.213**	**3**	**8.468**	**10**
Springiness index (none)	**0.843**	**3**	**0.898**	**10**
Area 1 (g s)	**101245**	**11**	**256256**	**10**
Area 2 (g s)	**96437**	**11**	**173749**	**14**
Work done in response to hardness 1	**72624**	**11**	**213637**	**10**
Work done in response to hardness 2	**67206**	**11**	**143662**	**16**
Recoverable deformation 1 (mm)	**3.188**	**3**	**4.142**	**19**
Recoverable deformation 2 (mm)	**3.442**	**4**	**3.849**	**15**
Recoverable work done 1 (g s)	**28615**	**11**	**41532**	**12**
Recoverable work done 2 (g s)	**30170**	**12**	**31879**	**14**
First peak (g)	121	81	4000	129

[a] The units are not customary ones. They were defined by the Company and are featured in the QTS 25 software. The speed of the probe must be taken into account in order to obtain correct units.
[b] Coefficient of variation (%): each value is the mean of 10 replicate measurements

Table 6. Results of principal component analysis

Penetration depth of 5 mm				Penetration depth of 10 mm			
No. of principal components	λ	Variance %	h^2	No. of principal components	λ	Variance %	h^2
1	12.72	74.83	74.83	1	9.91	58.33	58.33
2	2.38	14.02	88.84	2	3.15	18.51	76.83
3	1.35	7.97	**96.81**	3	2.16	12.73	**89.56**

n = 50, p = 17

2.4.1. Estimation with principal component regression. The product age (i.e., the period of time used for manufacture, ripening and storage) can be estimated by means of principal component regression from the principal components using the equation $y = a_1x_1+a_2x_2+...+a_nx_n +b$, where y is the product age (in days) and x_1, x_2, ..., x_n are the principal components. When three principal components are involved in the equation, the product age can be estimated with an accuracy of about 15–16 days. The standard errors of estimation for the two measuring conditions are 16.34^{a} and 14.74^{b}, $r_a = 0.603$; $r_b = 0.694$, (n = 50, P<0.001) where a is mode 1 and b is mode 2 of operation. For the overall period of 70 days the accuracy is 22%. The correlation between the measured and estimated values is illustrated in Fig. 2.

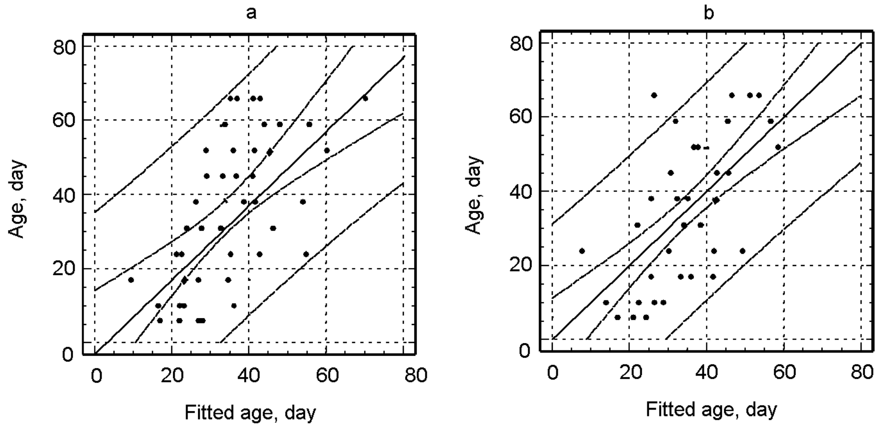

Fig. 2. Estimation of product age by principal component regression with two modes of operation.
a: Penetration depth of 5 mm, b: penetration depth of 10 mm, Y= age of cheese,
PCX=Xth principal component, SE= standard error.
a: Y= -1.845xPC1-6.044xPC2+3.078xPC3+34.799 SE=16.34 R=0.603 n=50 P<0.001
b: Y= -2.880xPC1 +5.852xPC2 –0.201xPC3+ 34.799 SE= 14.74 R=0.694 n=50 P<0.001

At a penetration depth of 10.00 mm, the estimation error is smaller than at a penetration depth of 5 mm. In both equations, the first principal components are used with negative coefficient.

2.4.2. Estimation with original variables. As 12 variables have significant weights in the first principal component, the product age was estimated with stepwise variable selection involving the 12 original variables by multiple linear regression analysis. The general formula of the estimation equation is $y = a_1x_1+a_2x_2+...+a_nx_n$, where y is the product age and x_1, x_2, ..., x_n are texture parameters. The correlation between the measured and estimated values is shown in Fig. 3.

At a penetration depth of 5 mm, the product age can be estimated with 2 variables (compression work 2 and decompression work 2) and a constant; and at a penetration depth of 10 mm also with 2 variables (chewiness and decompression work 2), but without a constant, with nearly the same accuracy. The estimation error at a penetration depth of 10 mm is slightly smaller (14.3 days), which is equivalent to an accuracy of 20% for the overall period.

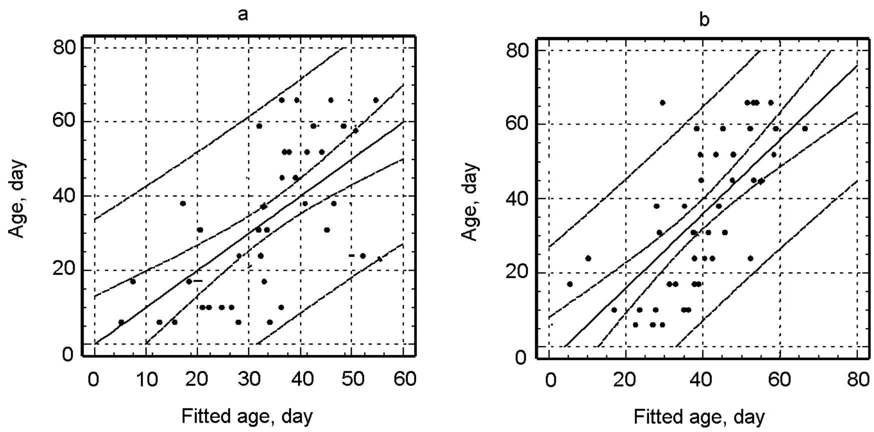

Fig. 3. Estimation of the age of the product with the original parameters with two modes of operation a: penetration depth 5 mm, b: penetration depth 10 mm, Y= age of the cheese, x= texture parameter, SE= standard error

a: $Y= 0.00201x_1-0.005x_2+52.66$ SE=15.66 R=0.634 n=50 P<0.001

b: $Y= -0.00137x_1 +0.000431x_2$ SE= 14.34 R=0.706 n=50 P<0.001

3. Conclusions

The correlations observed allowed 17 selected rheological characteristics to be replaced by 3 compressed variables. The values of the principal component weights indicated that the first principal component was determined mainly by 12 original variables in both measuring methods.

– The principal component values exhibited a multiple correlation with the cheese age. With the use of 3 principal components, the cheese age could be estimated.
– By selection of the original variables determining the first principal component with which the product age displayed a multiple linear correlation, equations were formed. By means of these equations, cheese age could be estimated with an accuracy of 16 days at a penetration depth of 5.00 mm and with an accuracy of 14 days at a penetration depth of 10 mm. The texture parameters used for estimation at a penetration depth of 5 mm correlated with the compression and decompression work measured in the second penetration cycle. At a penetration depth of 10.00 mm, of the bite-forming properties, the decrease in chewiness correlated with age and so did the compression work in the second cycle.
– It was concluded that, the data correlated with the product age at similar levels of significance under the two measuring conditions, however, the accuracy of the equation was higher at a penetration depth of 10.00 mm. Therefore, the use of a penetration depth of 10.00 mm is suggested for further testing of Hajdú cheese.
– This study may be useful for preliminary data for the qualification of samples. Highest accuracy requires more analytical data for many different samples.

References

ALY, M. E. (1994): Flavour-enhancement of low-fat Kashkaval cheese using heat- or freeze-shocked *Lactobacillus delbrueckii* var. *helveticus* cultures. *Nahrung*, *38*, 504–510.

A.O.A.C. (1990): Determination of total nitrogen in cheese. *Official methods of analysis,* 15th ed., A.O.A.C., Washington, DC, 955.30.

ARMERO, E. & COLLAR, C. (1997): Texture properties of formulated wheat doughs. Relationships with dough and bread technological quality *Z. Lebensmittelunters. Forsch*., *204*, 136–145.

BARA-HERCZEGH, O., HORVÁTH-ALMÁSSY, K., FENYVESSY, J. & ÖRSI, F. (2001): Suitability of texture parameters for characterization of Trappist cheese ripening. *Acta Alimentaria*, *30*, 127–143.

COCK, P. (1994): Starch compositions for texture-design of pasta cocktail snacks. *Food Ingredients Europe'94, Conference proceedings*, pp. 101–105.

FARKYE, N. Y. & FOX, P. F. (1990): Objective indices of cheese ripening. *Trends Fd. Sci. Technol.*, *1*, 37–40.

HUNGARIAN STANDARD (1987): *Tej- és tejtermékek érzékszervi elemző vizsgálata.* (Sensory analysis of milk and dairy products.) MSZ 12292-87.

HUNGARIAN STANDARD (1989a): *Hajdú sajt.* (Hajdú cheese.) MSZ 08-1243-1989.

HUNGARIAN STANDARD (1989b): *Sajt, ömlesztett sajt és túró kémiai és fizikai vizsgálata. A zsírtartalom meghatározása.* (Chemical and physical examination of cheese, processed cheese and quark. Determination of fat content.) MSZ 2714/1:1989.

HUNGARIAN STANDARD (1989c): *Sajt, ömlesztett sajt és túró kémiai és fizikai vizsgálata. A víz és szárazanyag-tartalom meghatározása.* (Chemical and physical examination of cheese, processed cheese and quark. Determination of water and dry matter contents.) MSZ 2714/2:1989.

HUNGARIAN STANDARD (1989d): *Sajt, ömlesztett sajt és túró kémiai és fizikai vizsgálata. A nátrium-klorid tartalom meghatározása.* (Chemical and physical examination of cheese, processed cheese and quark. Determination of sodium chloride content.) MSZ 2714/3: 1989.

JACKMAN, R. L. & YADA, R. Y. (1989): Multivariate analysis of functional and structure-related properties of whey-vegetable protein composites *Can. Inst. Fd. Sci. Technol. J.*, *22*, 260–269.

KALANTZOPOULOS, G. C. (1993): Production of cheese from sheep's milk. -in: FOX, P. F. (Ed.) *Cheese: chemistry, physics and microbiology*. Vol. 2, Chapman and Hall, London, pp. 518–528.

MILANOVIC, S., KALAB, M. & CARIC, M. (1998): Structure of Kashkaval curd manufactured from milk or UF retentate using enzymes of various origin. *Lebensm. Wiss. Technol.*, *31*, 377–386.

MOLNÁR, P. (1991): *Élelmiszerek érzékszervi vizsgálata.* (Sensory tests of foodstuffs.) Akadémiai Kiadó, Budapest, pp. 171–173.

PRENTICE, J. H. (1991): Cheese rheology -in: HUI, Y. H. (Ed.) *Encyclopedia of food science and technology*. Vol. 1. John Wiley & Sons, Inc.New York, etc. pp. 348–369.

SVÁB, J. (1979): *Többváltozós módszerek a biometriában.* (Multivariable methods in biometrics.) Mezőgazdasági Kiadó, Budapest, pp. 45–100.